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Trends and periodicities in the annual amount of dry days over Argentina, looking towards the climatic change

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Abstract. During the second half of the twentieth century, Southeastern South America experienced a positive trend in annual precipitation. Since Argentina is a country whose economy mostly relies on rain-fed agriculture, this trend has favoured the extension of the agricultural frontier, increasing the availability of productive lands. However, this precipitation increase was accompanied by greater interannual variability in precipitation, which increases the risk of droughts and their consequent negative impacts. In this work we analyze the temporal variability of the annual amounts of dry days (days without rainfall) over Argentina. We found significant trends in several regions of the country that reflects the increments in precipitation amounts. To analyze the interdecadal variability of dry days, we apply the wavelets analysis to the longest time series available, some of them from the beginning of the 20th century. This analysis identifies significant nonstationary periodicities between 8 and 16 years, mainly in the stations of the eastern region.

Keywords. Drought monitoring – Dry days – Decadal variability – Wavelet analysis – Argentina.

Tendances et périodicité de la quantité annuelle de jours secs en Argentine, en vue du changement climatique

Résumé. *Durant la seconde partie du vingtième siècle, le Sud-Est de l'Amérique du Sud a connu une tendance positive des précipitations annuelles. L'Argentine est un pays dont l'économie dépend majoritairement de l'agriculture, tributaire des précipitations, c'est pourquoi cette tendance a favorisé l'extension des frontières agricoles, augmentant ainsi la disponibilité des terres productives. Cependant, cette augmentation des précipitations a été accompagnée d'une variabilité interannuelle plus forte, ce qui a également augmenté les risques de sécheresse et leurs impacts négatifs conséquents. Dans cette étude, nous avons analysé la variabilité temporelle de la quantité annuelle de jours secs (c'est-à-dire les jours sans pluie) en Argentine. Des tendances significatives reflétant l'augmentation des précipitations ont été observées dans certaines régions du pays. Pour analyser la variabilité interdécennale des jours secs, nous avons utilisé l'analyse en ondelettes durant les plus longues séries de temps disponibles, certaines commençant au début du vingtième siècle. Cette analyse a alors permis d'identifier des périodicités non stationnaires significatives entre 8 et 16 ans, principalement dans les stations situées à l'Est de la région étudiée.*

Mots-clés. *Suivi de la sécheresse – Jours secs – Variabilité décennale – analyse par ondelettes – Argentine.*

I – Introduction

Global climate change have received great attention, especially the changes in average temperatures over the last century. However, not only the change in the average value of certain weather variables has negative consequences on society, but also changes in its variability, at global and regional levels. Precipitation varies significantly on a regional scale and changes of their spatial and temporal patterns can be particularly damaging (IPCC, 2007).

Some of these changes are too small to be detected on the scale of most global climate models, therefore, require an appropriate regional analysis because could potentially cause detrimental effects. During the second half of the twentieth century, Southeastern South America experienced a positive trend in annual precipitation. Since Argentina is a country whose economy mostly relies on rain-fed agriculture, this trend has favoured the extension of the agricultural frontier, increasing the availability of productive lands. However, this increase was accompanied by greater interannual variability in precipitation, which would increase the risk of droughts and their consequent negative impacts. Drought is an extreme phenomenon characterized by rainfall-deficient conditions, whose impact are evident in the environment, through the acceleration of desertification processes, generating increases in the risk of fire and limiting the availability of water for domestic and industrial use. It is also possible to highlight the impacts of drought at the socio-economic level, through the generation of declines in agricultural yields and livestock, affecting the production of hydropower and even causing human losses. Unlike floods and blizzards, whose impacts are felt in a matter of hours or days, a severe drought may not really start to have an effect for months or years (White and Walcott, 2009). In this work we analyze the temporal variability of the annual amounts of dry days (days without rainfall) over Argentina, with special attention to interdecadal and interannual variability in a regional approach.

II – Data and methods

The daily precipitation data were obtained from the National Weather Service of Argentina for 40 stations located north of 40°S (Table 1). For each station, the annual amount of dry days was calculated, considering a dry day as a day without precipitation. The linear trends were calculated in the common period 1960-2008, in which the stations had less than 10% of missing data. The rate of change in dry days with time was calculated by least squares linear fitting, which was evaluated using the Pearson correlation coefficient for the confidence levels of 90, 95 and 99%.

The stations have been grouped into 5 regions according to the regionalization obtained by Rivera *et al.* (2009). In order to analyze the existing periodicities in the annual amount of dry days, we selected one station for each region. These stations were chosen because of the length of their records, which sometimes cover more than 80 years, as well as the quality of their data. Two methods were used in order to identify these periodicities: an 11 year weighted running mean, following the weighting scheme used in Penalba and Vargas (2004); and a wavelet analysis, which was considered significant at 95%. These methodologies were applied to the original series of annual amount of dry days. The wavelet analysis offers a number of advantages in comparison with traditional Fourier analysis because it provides a time-scale localization of a signal (Pasquini *et al.*, 2006). In this analysis, we will use the Morlet as the mother wavelet function, which is one of the most widely used in geophysical signal detection. The theoretical aspects of wavelet analysis can be found in the works of Torrence and Compo (1998) and Labat (2005), among others.

III – Results and discussion

1. Trends for the period 1960-2008

The most important trends in the annual amount of dry days during the period 1960-2008 are in the Central region of Argentina (Table 1). There is a predominance of negative significant trends in the Central-west region, indicating that this region experienced a decrease in the amount of dry days during the last 49 years (Table 1). This decrease is accompanied by annual precipitation increases in recent decades (Castañeda and Barros, 1994; Minetti *et al.*, 2003;

Barros *et al.*, 2008). The predominance of negative trends is also evident in the Pampas region and agrees with the results obtained by Penalba and Vargas (2004) for annual precipitation. In the remaining regions, the sign of the trends is not well defined. The positive trends in the Central-east region are mostly significant. According to the positive trends in precipitation in this region (Penalba and Vargas, 2004; Pasquini *et al.*, 2006) this last result could imply an increase in the daily precipitation totals in those stations and probably in the occurrence of extreme events. We found no significant trends in the annual amount of dry days north of 30°S.

Table 1. Location, record period and trends in the annual amount of dry days for the period 1960-2008 of the analyzed rainfall stations

Region†	Station	Latitude (S)	Longitude (W)	Period	Trend (dry days/decade)	p-value
NW	Orán	23°09'	64°19'	1957-2008	-0.5	n.s.
NW	Salta	24°51'	65°29'	1926-2008	0.3	n.s.
NE	Las Lomitas	24°42'	60°35'	1959-2008	1.8	n.s.
NW	Santiago del Estero	27°46'	64°18'	1931-2008	-1.2	n.s.
NE	Posadas	27°22'	55°58'	1957-2008	-0.8	n.s.
NW	La Rioja	29°23'	66°49'	1941-2008	1.0	n.s.
CE	Villa María del Río Seco	29°54'	63°41'	1931-2008	0.7	n.s.
CE	Ceres	29°53'	61°57'	1931-2008	-0.2	n.s.
NE	Reconquista	29°11'	59°42'	1948-2008	0.6	n.s.
NE	Bella Vista INTA	28°26'	58°55'	1929-2008	-0.6	n.s.
NE	Pcia. Roque Saenz Peña	26°45'	60°24'	1957-2008	-0.4	n.s.
NE	Paso de los Libres	29°41'	57°09'	1956-2008	0.5	n.s.
NE	Monte Caseros	30°16'	57°39'	1931-2008	-0.5	n.s.
CW	Villa Dolores	31°57'	65°08'	1930-2008	-0.3	n.s.
CE	Córdoba Aero	31°19'	64°13'	1956-2008	2.0	<0.1
CE	Pilar Observatorio	31°40'	63°53'	1925-2008	-1.2	n.s.
CE	Sauce Viejo	31°42'	60°49'	1958-2008	2.4	<0.05
CW	Mendoza Observatorio	32°53'	68°51'	1957-2008	-4.5	<0.01
CE	Gualeguaychú	33°00'	58°37'	1931-2008	-0.8	n.s.
CW	San Luis	33°16'	66°21'	1951-2008	-1.7	n.s.
CW	Villa Reynolds	33°44'	65°23'	1956-2008	-3.1	<0.05
CE	Río Cuarto	33°07'	64°14'	1931-2008	3.0	<0.01
CE	Marcos Juarez	32°42'	62°09'	1953-2008	-0.7	n.s.
CE	Rosario	32°55'	60°47'	1936-2008	2.2	<0.1
CW	Malargüe	35°30'	69°35'	1956-2008	-4.9	<0.01
CW	San Rafael	34°35'	68°24'	1956-2008	-1.8	n.s.
P	General Pico	35°42'	63°45'	1956-2008	-0.5	n.s.
P	Santa Rosa	36°34'	64°16'	1938-2008	-2.6	n.s.
P	Laboulaye	34°08'	63°22'	1940-2008	-1.3	n.s.
P	Pehuajó	35°52'	61°54'	1959-2008	0.3	n.s.
P	Junín Aero	34°33'	60°55'	1959-2008	-0.5	n.s.
P	Nueve de Julio	35°27'	60°53'	1931-2008	-1.7	n.s.
P	OCBA	34°35'	58°29'	1909-2008	-1.2	n.s.
P	Punta Indio	35°22'	57°17'	1957-2008	-1.4	<0.05
P	Dolores	36°21'	57°44'	1931-2008	1.7	n.s.
P	Tandil	37°14'	59°15'	1960-2008	1.2	n.s.
P	Mar del Plata	37°56'	57°35'	1951-2008	1.7	n.s.
P	Coronel Suarez	37°26'	61°53'	1937-2008	0.1	n.s.
P	Bahía Blanca	38°44'	62°10'	1956-2008	-0.9	n.s.
CW	Neuquén	38°57'	68°08'	1957-2008	0.2	n.s.

†Regions: CE (Central-east), CW (Central-west), NE (Northeast), NW (Northwest), P (Pampas).
n.s.: not statistically significant; p < x: statistically significant with a probability x.

2. Interannual and interdecadal variability

Figure 1 shows the annual amount of dry days time series with their nonlinear trends and the 11 year weighted running mean for each representative station per region. Nonlinear trends were estimated using a cubic polynomial, since it is not distorted by extreme values (first and last values of the series). Most of the regions exhibit an apparent downward trend, except for the Northeast region, which is going to drier conditions. Both the Northeast and Central-east regions show a recent positive trend since 1990s, with the maximum value of the time series in 2008. This is in concordance with a severe drought which affected both regions and continued in 2009. Furthermore, the change in the trend was due to the dry events in 1988-1989, 1995-1996 and 2003. The interannual variability shows great difference between the regions, responding to different precipitation regimes.

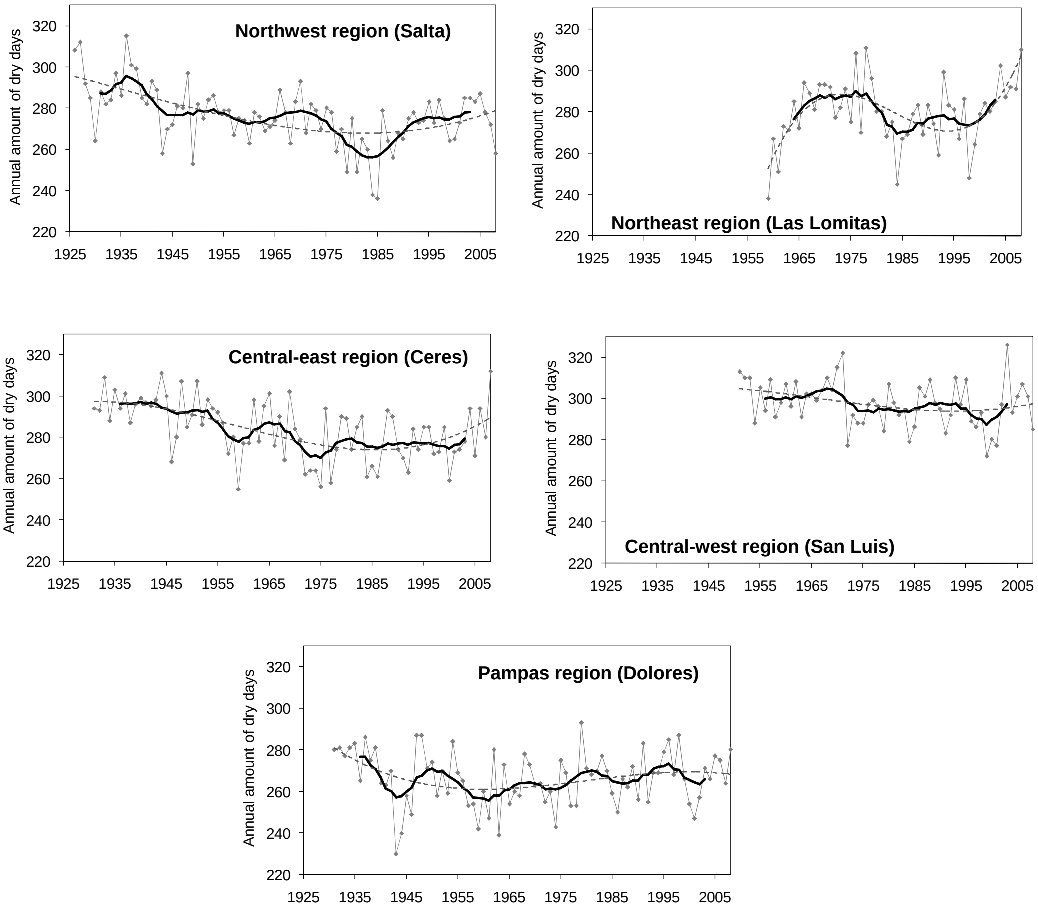

Fig. 1. Time series of annual amount of dry days for the five stations selected (thin line) with its running mean (thick line) and a cubic polinomial fit (dotted line).

Figure 2 shows the results obtained after the wavelet analysis to the previously selected stations. The regional differences in the behaviour of the annual amount of dry days are also reflected in these results. Most regions has significant periodicities between 10 and 30 years.

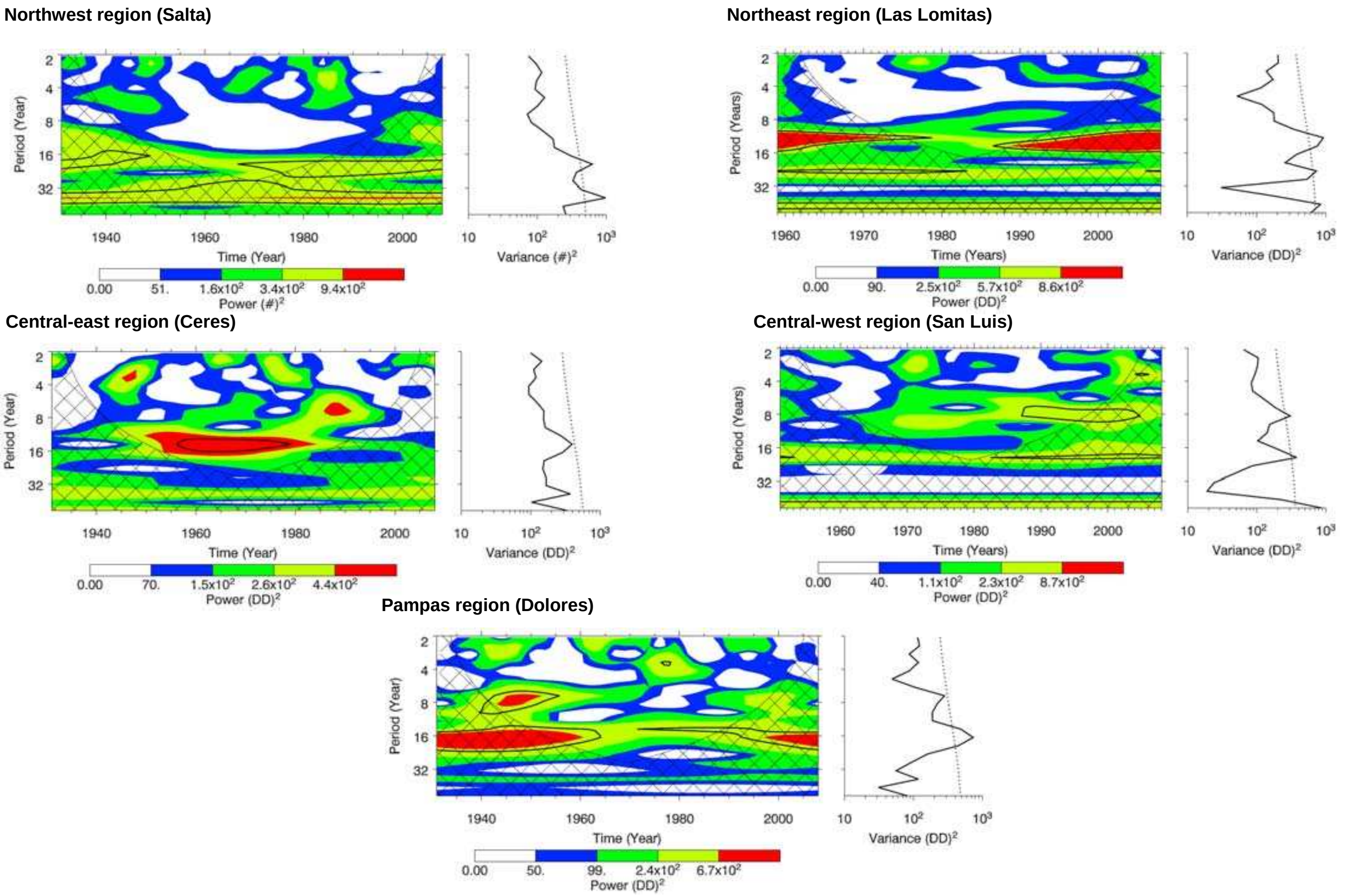

Fig. 2. Wavelet transform results of the annual amount of dry days time series. The thick contour encloses regions of greater than 95% confidence for a white-noise process. Cross-hatched regions on either end indicate the "cone of influence", where edge effects become important. It should be noted that the x-axis scale changes between graphs.

The Northwest region show a near bidecadal periodicity, significant after the 1960s, although part of this variability is within the cone of influence. A significant signal between 14 and 24 years is evident in the Pampas region, interrupted during the second half of 1960s decade. This signal has a lower frequency until 1965 and then changes to higher frequencies between 1970 and 1990. Part of this signal is within the cone of influence. This change in the signal can be observed in Fig. 1. Likewise, a significant ~14 year period has been identified over the Central-east region between 1950 and 1980, which is evident in its time series (Fig. 1). The Northeast region shows significant periodicities at 10-16 years and 24 years. Until the 1980s, the signal appears as the combination of these two variabilities, whereas by mid-1980 only appears a signal around 10-16 years. This agrees with the behaviour of the 11-year filter in Fig. 1, but it must be taken into account that much of this variability falls within the cone of influence. There is also evidence of variability on interannual scale (6-8 years) in the Central-west region, which is significant since the mid-1980s, and in the Pampas region during the 1940s and the first half of the 1950s. The Northeast and Central-west regions have significant periodicities greater than 50 years, representatives of a long-term trend. However, they should be considered not significant in the analysis as they are within the cone of influence of the wavelet. Furthermore, it should be noted that these trends differ from those obtained during the period 1960-2008 (Table 1), given the years difference. Another long-period cycle has been identified in the Northwest region, with a significant ~40 year period.

IV – Conclusions

Through this work were identified periodicities in the annual amount of dry days in the interannual and interdecadal ranges in north-central portion of Argentina during the past 80 years. The most significant cycles were observed in the range of 10 to 30 years, but also found variations in the interannual scale, depending on the region. Although there were trends toward a decrease in the annual amount of dry days, in some regions these trends have begun to reverse. The drought occurred in 2008-2009 was extreme in several stations in the country (Skansi *et al.*, 2009), which warrants a continuous regional monitoring of the evolution of these adversities and its long term trend.

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